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Preparation and Characterization of Semiconductor Thin Films

B. N. JAGADALE[1] and GURURAJ HOSAMANI[2]

[1]Department of Electronics,
Kuvempu University, Shankaragatta, INDIA.
[2]Department of Electronics
Karnataka University, Dharwad, INDIA.

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ABSTRACT

In the present work, the CdTe & ZnTe thin films of different thickness were prepared in the vacuum chamber using thermal evaporation using vacuum coating unit. The prepared films were cut into pieces and characterized for structural and optical properties. The structural analysis of as prepared samples was carried out by the XRD (PHILIPS PW 3710). The structural analysis showed that increase with thickness, crystallanity and grain size increases where as strain and dislocation density decreases. With increase in deposition time, the nucleus size increases leading to larger clusters, their coalescence and formation of continuous films and hence also the grain size of these films.

Keywords: Semiconductor thin film, CdTe and ZnTe.

1. INTRODUCTION

The aim has been to present the fundamentals of thin films in a simple and logical manner through keeping link and continuity amongst different topics dealt in different chapters. A casual comparison of film behavior and physic-chemical characteristics revealed the sensitivity of film properties on the preparative conditions, film structures presence of thickness expression for ultra thin films. Numerous applications of films led to intense studies of them especially to development and prepare better films with specialized properties from newer compounds or composite materials. Thin film science has received tremendous attention in the recent years especially after the world war because of numerous applications in the diverse fields such as electronic industries, military weapon systems, space science, solar energy

utilization, optical and superconducting films, high memory computer elements, sensors, microelectronic and hybrid circuits and others. Due to such vast applications researches are going on not only in the field of basic thin film physics, but also in material science, thin film circuit designs, production engineering concerning thin films, etc. to cop up the demand of industries.

The structural, optical and electrical properties of thin films mainly depends on the deposition parameters such as**:** rate of deposition, substrate temperature, environmental conditions, residual gas pressure in system, purity of material to be deposited, inclusion of foreign matter in the deposit, inhomogeneity of the film, structural and compositional variations of film in localized and wider area. A transition from bulk to thin film state may even cause drastic change in its properties. Such as highly conducting sodium, potassium, rubidium, also gold, platinum etc. having positive temperature coefficient of resistance (TCR) in bulk form shows negative TCR in thin film states thus behaving as semi conducting films. Bulk bismuth and antimony which are metallic in nature behave as semiconductors in thin film state.

In view of these, present work constitutes an effort to fabricate & to study the structural and optical properties of two most important II-VI compound semiconductors viz. Cadmium Telluride (CdTe) and Zinc Telluride (ZnTe) thin films. Therefore the results obtained would help us to assess the structural and optical properties of CdTe and ZnTe thin films prepared at different thickness for device applications. The II–VI semiconductors, such as CdTe and ZnTe, have drawn scientists' attention for a long time as perspective materials to produce a wide range of devices for microelectronics. Cadmium telluride single crystals are used as X-ray and gamma radiation detectors, whereas CdTe thin films can be used as base layers in converters of solar energy. The wider band-gap ZnTe is a promising material for green lasers. ZnTe thin films can be used as buffer layers in infrared detectors and solar cells.

Scope of using CdTe and ZnTe semiconductors

- Cadmium telluride (CdTe) and Zinc telluride (ZnTe) have been regarded as promising semiconductor materials for hard X-ray and gamma-ray detection.
- The large band-gap energy of CdTe (Eg-1.5 eV) and ZnTe (Eg-2.4 eV) allows us to operate the detector at room temperature.
- The high atomic number of the materials (ZCd =48, ZZn =30 & ZTe =52) gives a high absorption efficiency in comparison with Si and Ge.
- Both can be doped with both n-type and p-type

2. OPERATION OF COATING UNIT

First the Hind High Vacuum Coating unit is switched on. Rotary pump is switched on. The vacuum chamber and the Air admittance valve are closed. The roughing valve is opened. Now the pirani gauge is switched on and roughing is maintained till the reading is reached 0.05 mbar. After reaching rough vacuum, valve is switched to backing. Now a constant water

supply is maintained and all the side doors are closed. Diffusion Pump (DP) is switched on, it takes half an hour to heat, at this stage we can open the vacuum chamber. If opened, the above steps are repeated. When the Silicon Oil gets heated the high vacuum valve is opened. When the penning gauge reading is $2x10^{-5}$ mbar CB1 and rotary drive are switched on. Now the rotary drive is controlled by rd control. Current is maintained by controlling the LT /HT controller. Thickness of the film is noted in the thickness monitor. This process is continued till the required thickness is obtained.

PREPARATION OF CdTe SEMI-CONDUCTOR THIN FILM

CdTe thin films were prepared using a vacuum coating unit (Hind High Vacuum Company, Bangalore) Model 12A4D. Pure CdTe (Sigma Aldrich, 99.99%) was used as a source material for the evaporation. The material was placed into molybdenum boat with a small dimple at the center to act as a point source. Cleaned glass slides were used as a substrate. The source-substrate distance was maintained at 13.5 cm. Rotary drive was used to obtain the uniform coating. The rate of evaporation was maintained at ~1.4 Å/sec under the vacuum of 1×10^{-5}mbar. All the films were prepared at 150°C substrate temperature. Rate of evaporation and thickness were measured using Digital Thickness Monitor (Model DTM 104) fixed to the unit. All the samples were prepared for different thickness with similar deposition conditions.

PREPARATION OF ZnTe SEMI-CONDUCTOR THIN FILM

ZnTe thin films were prepared using a vacuum coating unit (Hind High Vacuum Company, Bangalore) Model 12A4D. Pure ZnTe (Sigma Aldrich, 99.99%) was used as a source material for the evaporation. The material was placed into molybdenum boat with a small dimple at the center to act as a point source. Cleaned glass slides were used as a substrate. The source-substrate distance was maintained at 13.5 cm. Rotary drive was used to obtain the uniform coating. The rate of evaporation was maintained at ~1.4 Å/sec under the vacuum of 1×10^{-5}mbar. All the films were prepared at 150°C substrate temperature. Rate of evaporation and thickness were measured using Digital Thickness Monitor (Model DTM 104) fixed to the unit. All the samples were prepared for different thickness with similar deposition conditions.

RESULTS AND DISCUSSION

The structural analysis of as prepared samples was carried out by the XRD (PHILIPS PW 3710). The optical properties were studied using UV-Vis spectrophotometer (Model Shimodzu 1650 PC).

STRUCTURAL PROPERTIES OF CdTe THIN FILMS

Structural analysis of the prepared samples was carried out by X-Ray diffractometer. XRD patterns of CdTe films for different thickness are shown in fig.4.1. The presence of peak at $2\theta=23.76^{o}$ in (111) direction reveals that all the films are

crystalline in nature. The observed values in the XRD and those of JCPDS (ICDD No. 89-3053) data is found in fair agreement between them. All the films have cubic structure with face centered lattice with lattice constant 6.480Å.

It can be seen from the XRD graph that the peak intensity of the films increases with increase in the thickness. The lattice parameters of the films were calculated using the Bragg's formula:

$$2d \sin\theta = n\lambda \quad (1)$$

The grain/crystallite size of the films were calculated from the XRD using Scherer's relation,

$$D = \frac{k\lambda}{\beta \cos\theta} \quad (2)$$

Where k = 0.94 is a constant, λ - the wavelength of radiation, β - the full width half maximum and θ - the diffraction angle. The micro strain (ε) and the dislocation density (δ) estimated using the equations 3 & 4 and presented in table

$$\varepsilon = \frac{(\beta \cos\theta)}{4} \quad (3)$$

$$\delta = \frac{1}{D^2} \quad (4)$$

It can be noticed from the table that grain size increases with increase in film thickness.

Strain and dislocation densities decreases with increase in film thickness.

Table.1 XRD analysis of the CdTe thin films prepared at different thickness

Thickness of the sample (nm)	d-spacing (Å)	D (nm)	strain	Dislocation (E+14)
100	3.51898	40.4217	27.77373	6.12029
200	3.52584	44.1385	25.43492	5.13292
300	3.51144	46.15	24.32633	4.69523
400	3.51528	49.0659	22.88064	4.15374

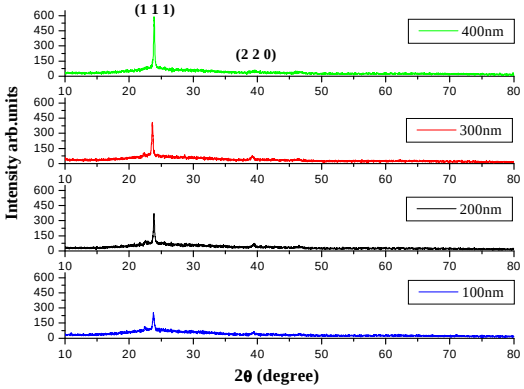

Fig 1.1 XRD parameters of CdTe thin films

CONCLUSIONS

- CdTe and ZnTe thin films were prepared using resistive heating method for different thickness from 100nm to 400nm.
- Structural characteristics were by X-Ray diffractometer and Optical properties were studied using UV-Vis spectrophotometer.
- The structural analysis showed that increase with thickness, crystallanity and grain size increases where as strain and dislocation density decreases. With increase in deposition time, the nucleus size increases leading to larger clusters, their coalescence and formation of continuous films and hence also the grain size of these films.

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